W-band klystron upconverter driven by pseudospark-sourced electron beam

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***Abstract*—In this paper, a three-cavity klystron upconverter operating at W-band is presented. It is predicted to generate 40 W when driven by a 30 kV, 0.2 A electron beam. Pseudospark-sourced electron beam after post-acceleration was proposed to be used with the klystron upconverter because it has the advantage of low energy spread, high current density, and no need of any external guiding magnetic field.**

***Keywords*—klystron upconverter; pseudospark discharge; post acceleration;**

I. Introduction

Low-cost millimeter-wave sources are always in great demand for many applications due to an atmospheric transmission window in the frequency range of 90-110 GHz (W-band). In W-band the solid-state source can achieve watt level output power, and fixed frequency gyrotron oscillators can generate MW level output power [1] while tuneable gyrotron backward wave oscillators can achieve ~10kW [2]. The extended interaction klystron (EIK) [3] and traveling wave tubes [4] can generate kilowatts and hundreds of watts of power respectively, .

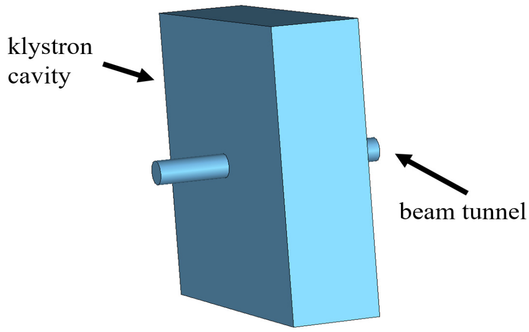
The major challenge of millimeter-wave sources is the power reduction caused by the small dimensions due to the increase in the operation frequency. Thus microwave devices operating at higher order modes can be a potential solution [5]. When operating at a higher order mode, the dimensions of the interaction waveguide can be larger therefore allowing higher power capability. The larger dimension of the interaction waveguide enables higher power capability as well as reducing the fabrication difficulty and minimising the cost.

Further reduction in the overall cost can be achieved by using the pseudospark-sourced electron beam. It has the advantage of much higher current density compared with the conventional thermionic electron beam. More importantly, the extracted electron beam can be focused by the ion channel formed due to ionization of background gas molecules by beam front itself. Therefore there is no need of any external guiding magnetic field and can significantly simplify the whole system and reduce the cost. Also the pseudospark discharge operates at a pulse mode and a compact pulsed power supply can be used.

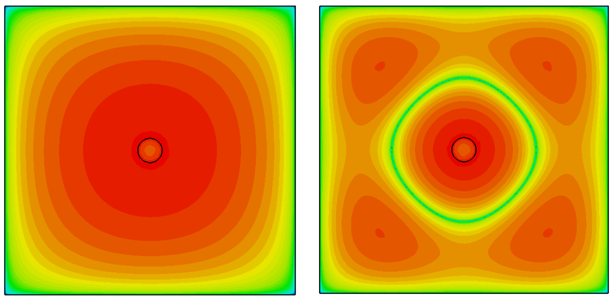
Pseudospark sourced electron beam has been used to generate high frequency radiation effectively in the past [6, 7]. In this paper, a W-band klystron upconverter driven by pseudospark-sourced electron beam is presented.

II. W-band upconverter

The klystron cavity can operate at a higher order mode. Fig. 1 shows the geometry of a cuboid cavity and its electric field patterns of the TM_{110} and TM_{330} modes. The eigen frequency of the TM_{330} mode is about 3 times of the fundamental TM_{110} mode.



(a)



(b) (c)

Fig. 1. The geometry of the cuboid cavity (a), and the electric field patterns of the TM_{110} (b) and TM_{330} modes (c).

A three cavity klystron upconverter with an output frequency of 105 GHz was designed. The input cavity and intermediate cavities were designed to operate at the fundamental mode, while the output cavity operates at the higher order mode. The benefit of this configuration is that an input source with a lower frequency in Ka-band (35 GHz) can be used to drive the amplifier removing the need to use often a

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more expensive W-band source. The whole structure of the three-cavity klystron upconverter is shown as in Fig. 2.

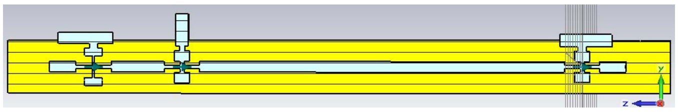

Fig. 2. The whole structure of the three-cavity klystron upconverter.

In particle-in-cell (PIC) simulations, when the klystron upconverter is driven by a 30 kV, 0.2 A electron beam, the output power is predicted to be about 40 W.

III. PSEUDOSPARK-SOURCED ELECTRON BEAM WITH POST ACCELERATION

The mechanism of the pseudospark discharge has been experimentally studied in reference [8]. Following the hollow cathode discharge stage, is the conductive stage, also called the pseudospark discharge stage. Electron beams extracted during the hollow cathode discharge stage have been successfully used to drive a few microwave devices, such as the backward wave oscillator and the extended interaction oscillator [9, 10]. It was found that only the electron beam generated during the hollow cathode discharge stage have sufficient energy for the beam wave interaction. The electron beam during the conductive stage is of low energy and not able to drive any energy-sensitive devices. An advanced post-acceleration technology is used to further accelerate the long duration, low energy electron beam generated during the conductive stage. The electron beam after post-acceleration will have small energy spread and longer pulse duration, which will increase the output power of microwave devices.

The post-acceleration technology demonstrated in reference [11] requires an additional power supply. Recently, a compact post-acceleration circuit was developed and only one power supply is needed, as shown in Fig. 3. It can be seen that a single-gap pseudospark discharge cavity and also one single post-acceleration gap were used.

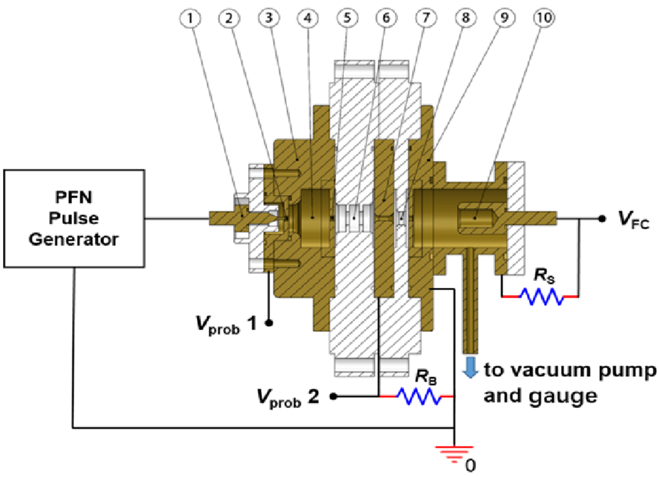

Fig. 3. Pseudospark discharge system with post acceleration gap (8).

With a PFN Blumlein pulse generator, the pseudospark discharge will be able to operate at different pulsed voltages. The experiments on the pseudospark discharge system with post acceleration is currently being conducted and the results will be reported.

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